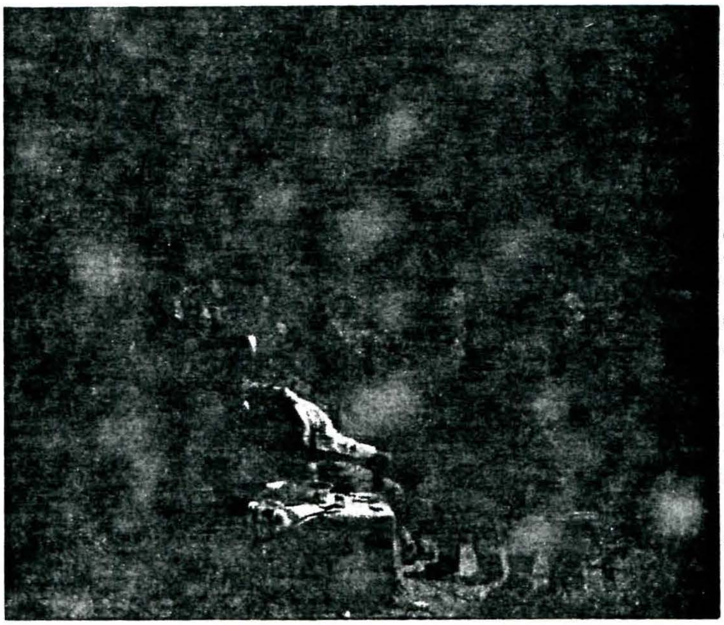
Tomorrow's electronic hospital is here today

Computer use is revolutionizing not only hospital laboratories and record-keeping, but also emergency treatment, diagnostics, and intensive care



Boston Medical Library, the Francis A. Countway Library of Medicine

First Operation Under Ether [1846], *Robert Hinkley, 1882*

Until recently, doctors seeking information on patients at most hospitals had to visit a storage room and pore through files that were hand-written and perhaps intelligible only to their authors. But at state-of-the-art facilities like LDS Hospital of the University of Utah in Salt Lake City, doctors need only tap a nearby terminal for patient records. The records are displayed in a clear, standardized format. Moreover, the computer can help the physician interpret the data and even help prescribe appropriate therapy.

Computers have modernized virtually all operations at LDS—clinical laboratory analyses, emergency treatment, radiology, intensive care, and record keeping—and have integrated them into a smooth-running whole. The system is safer, faster, and more responsive to the needs of patients than it used to be. It has also reduced or eliminated many tedious tasks for doctors and nurses, freeing them for more personal attention to patients. The next great challenge lies in the development of more widely accepted medical-information standards so a patient's records can be transmitted from one hospital to another as quickly and productively as they are passed from one department to another at LDS.

Computers crucial to emergency treatment

How critical is the computer to the operations of LDS? Suppose a 30-year-old man is admitted through the hospital's emergency room with multiple injuries suffered in an automobile accident. The emergency-room staff quickly attaches him to microcomputer-based equipment at his bedside that monitors his vital signs, displaying them on a terminal. If any of these vital signs changes drastically for the worse, the computer triggers an alarm. The patient's name is then logged into the hospital's central system, which searches its data base for a prior admittance.

If the patient has been in the hospital within the last 15 years, his history will be immediately available to the emergency-room staff. Otherwise the staff members enter such information as age, sex, and weight. Following this, the hospital's entire electronic network—24 computers, 250 terminals, and 70 printers—is notified and appropriate record files are prepared. Blood samples drawn from the patient are sent to the clinical and blood-gas laboratory, where personnel have already been notified of the upcoming order via the computer network. As soon as they have analyzed the sample, they feed the results through their laboratory's computer, which also conducts an initial check for accuracy. Then these results are logged into the hospitalwide system, which evaluates them against normal reference values, based on the information it possesses about the patient's age, sex, and body size. Within two minutes the data are interpreted and the results—including any indications of life-threatening conditions—are printed out in the emergency room. They are also available for review on any of the hospital's terminals.

Reed M. Gardner LDS Hospital, University of Utah

If X-rays of the patient are taken in the emergency room, they may be sent for analysis to a radiologist, who, like the clinical laboratory staff, has been alerted by his own terminal. The computer, based on its own knowledge of the patient's location, sex, age, and ailment, can prompt the radiologist with various likely interpretations of the X-rays, speeding his analysis. He then can quickly select one of the displayed interpretations for transmission to the emergency room.

After appropriate care in the emergency room, the patient may be transported to an operating room for surgery, where all the data previously generated about the patient are available. Any surgical procedures performed here are also entered into the patient's record by a nurse or technician. After surgery, the patient will probably be sent to the hospital's shock-trauma intensive-care unit, where microcomputer-based sensors continue to monitor his heart rate, blood pressure, and other critical parameters. As in the emergency room, this equipment will automatically alert the staff if any dangerous changes in the patient's status occur.

Information on the patient is formatted for display according to major organ systems. Since many critically ill patients have suffered or may suffer multiorgan failure, this format allows the medical staff to review each organ system rapidly and, if necessary, to make prompt therapeutic decisions. Information of this kind, for example, is provided to the patient's physician as he makes his morning rounds. Any new information the physician adds to the formatted "rounds report" is automatically organized within the same format.

Prescriptions automatically checked for errors

Any drug orders for the critically ill patient are also entered through the computer. The initial order triggers the following sequence of events: the order is stored on the patient's data file, where it becomes available for review on any terminal; a computerized drug schedule is initiated so that whenever the drug is given again, a quick review of the schedule allows prompt drug entry into the patient's file; the drug order is processed through a pharmaceutical expert-system program that can determine if the order is safe, based on what the computer knows about other, possibly incompatible, drug orders or about the patient's laboratory data or history; the patient's record is updated to indicate that the drug has been given; and the patient is billed.

Finally, if anything happens to the patient that someone contends was the result of an error by the hospital's staff, the computer's data base provides the official legal record.

Computers have been used in hospitals for over 25 years. In conjunction with a variety of electronic sensors and instrumentation, they have led to dramatic advances in the ability of doctors to diagnose and monitor patients. Fast, computerized analysis of electrocardiograms, for example, are now common even in the smallest hospitals. Computers have added to the speed and accuracy with which clinical laboratories give data to physicians. Computers are also largely responsible for recent breakthroughs in radiography, including computerized axial tomography and nuclear-magnetic-resonance imaging. Nevertheless, in most hospitals today computers primarily serve the same function they served 20 years ago: billing patients.

When adapted for clinical applications, computers have usually remained stand-alone systems. Few hospitals have attempted, as LDS has, to integrate these various units into a single interconnected system. This system, which began to take shape in the late 1960s with the automation of such simple tasks as blood-pressure measurement, has evolved from an unusually close interaction between physicians and computer engineers. The engineers have studied physiology and medicine, and the physicians have studied computers and data bases.

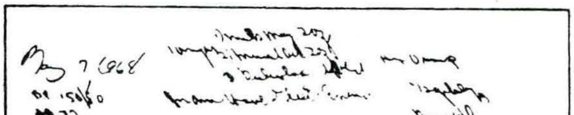
Reliability a must

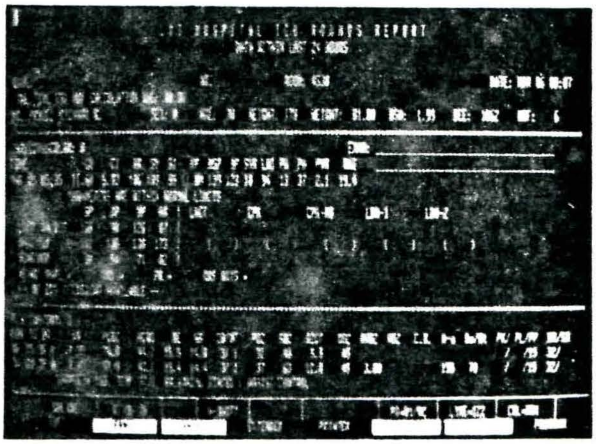
Probably the most important criterion for any system used in health care is reliability. A loss of data or a shutdown of a computer-controlled life-support system could result in a patient's death. To achieve reliability, LDS has deployed computers with both built-in hardware redundancies and software intelligence to keep the system operational in the event of a hardware failure.

Computers lead to overhaul of system for writing and reading medical records

In the past, a patient's medical record was often handwritten, scribbled down by a doctor in his office or at the patient's bedside. (The example below is from *Your Health Care and How to Manage It*, by L. L. Weed, Essex Publishing Co.) But due to the idiosyncracies of notation and handwriting that commonly marked such a document, it often would prove of little value to any would-be reader other than its original author. Thus a clinician seeking to know a patient's prior history might have to consult the previous doctor directly and ask him to interpret his old records or simply to recall their gist.

Example of handwritten medical record





Patient data displayed on computer terminal

Patient records at LDS Hospital of Salt Lake City, Utah, are now stored on a central computer system. This system eliminates the need for clinical personnel to go to a physician's office or to a central storage room in search of information. At LDS, the information can be obtained from any one of more than 250 terminals situated throughout the hospital: in nursing divisions, laboratories, the pharmacy, admitting areas, administrative offices, and physicians' offices. The information is stored in a central data base. But some recent information is also stored on microprocessors distributed throughout the hospital for faster retrieval.

Standards have been developed for the entry of data, so that, once trained, any member of the clinical staff can understand the entry of any other member of the staff, as well as data produced by automatic monitors and the like. Information is commonly formatted according to major organ systems, such as the heart, lungs, or brain. For example, if a doctor wants to know the status of a patient recuperating from heart surgery, he can call up the cardiac portion of the patient's latest rounds report, an example of which is displayed above.

—*John P. Horgan*

Medical technology offers hope for victims of Alzheimer's disease

The ongoing electronics revolution has triggered a corresponding surge in the ability of physicians to peer into and understand the human body. Almost daily, breakthroughs in imaging technology are reported that promise major benefits to vast numbers of individuals. Perhaps no recent development exemplifies the breadth of electrotechnology's potential better than the use of positron-emission tomography (PET) to study Alzheimer's disease. Almost unknown to the lay public a few years ago, Alzheimer's disease has been found to be the leading cause of senility in the United States and one of the leading causes of death; according to a recent congressional estimate it costs the nation about $26 billion each year. Now, thanks in part to the efforts of technology-minded clinicians like Robert P. Friedland and Thomas F. Budinger of the University of California at Davis and Berkeley, respectively, whose report we publish below, Alzheimer's disease is yielding its secrets. —Ed.

Over the past four years we have performed moment-to-moment, full tomographic reconstructions on Alzheimer's-disease patients using positron-emission tomography at the Donner Laboratory of the University of California, Berkeley. Using injections of a glucoselike compound tagged with a short-lived radioactive isotope, we have discovered that portions of the brain of patients in the early stages of the disease have decreased metabolism of glucose, the brain's most critical nutrient. The metabolic rate in these regions, which are responsible for memory, language, and other higher functions, drops further as the disease progresses.

At present, we can only speculate on the cause and meaning of this decreased metabolism. It may result from a lower metabolic rate in each cell in the affected region, or a loss of cells. These conditions may in turn result from a slow-acting viral infection, from abnormal blood-flow control, from a defect in the brain's system for transmitting impulses from neuron to neuron, or from some other cause yet to be defined. Further refinements in PET technology may eventually provide the added temporal and spatial resolution we need to pinpoint the origins of the disease.

But the recent PET findings are also important for having targeted areas of the brain for closer investigation by other means. Nuclear-magnetic-resonance imaging, though incapable of discerning the decreased metabolism in the brains of two of our Alzheimer's patients, could give valuable additional information if focused on those areas specified by our PET studies. The PET glucose-tracer findings also point the way toward further PET studies with tracers aimed specifically at those disease processes most likely to cause Alzheimer's disease.

—Robert P. Friedland, M.D.
University of California, Davis, and
VA Medical Center, Martinez, Calif.; and
Thomas F. Budinger, M.D.
Donner Laboratory,
University of California, Berkeley

Reliability is also maintained by the storage of information in a central data base. But to enhance the system's speed, the most current patient data are also stored in distributed microprocessors and intelligent terminals. This distribution increases not only the speed with which doctors or nurses can review patient data at terminals throughout the hospital; it also increases the speed with which data can be processed in the central system.

Despite these technical achievements, the success of the system at LDS hinges to a large degree on acceptance by its users, especially doctors and nurses. This acceptance did not occur overnight. Initially doctors tended to complain that they had no time to learn how to interact with the new system. Some said the system would distract them from the proper focus of their attention—the patient. They worried that some of the applications developed for the computers were encroaching on their decision making.

But after they became accustomed to the new system, most doctors and nurses reported great satisfaction with it. It eliminated much redundant charting and data gathering, and—in the case of doctors—allowed them to view patients' records from terminals installed in their homes. As for the system's interpretative and decision-making capabilities—used, for example, to reject a potentially dangerous prescription or to advise a chest X-ray for a patient who showed symptoms of pneumonia—doctors came to see them not as threats, but as a safety net.

Another objection to the computerization of the hospital—that it would lead to impersonal and inhuman treatment, as the staff paid more attention to machines than to their patients—has also been put to rest. Because of the significant decrease in the time that they must spend on paperwork, doctors and nurses have, in fact, been freed to spend more time in direct contact with their patients, thus providing even more humane care.

Development of protocols a challenge

Of course, there remains a great deal of room for improvement in the way computers are used to provide better health care in hospitals. Computers and monitoring systems used in intensive-care units still lack the key investigative abilities of any physician—visual examination, palpation, and auscultation. Methods should be developed to acquire this type of data and make them available for analysis by the computer. Mechanisms for acquiring critical data values must also be developed. For example, the pH value of a blood sample might give the computer the vital piece of information it needs, along with other data, to make a speedy therapeutic decision. Perhaps in situations like this, the computer could be programmed to request the data.

The computer has also not eliminated another persistent problem for doctors—inaccurate or erroneous data caused, for example, by someone transposing digits when entering a number. The computer can prevent data errors by checking to see that entries fall within certain parameters. But it does not yet have insight equal to a good physician's instinct. However, the problem could be alleviated through the use of better data-collection protocols.

The development of interpretative and therapeutic protocols is the greatest challenge of all. Up to now, medicine has not been taught or applied as a strictly quantitative science. Much could be accomplished through the development by physicians, nurses, and knowledge engineers of more quantitative medical methods, which could be more easily and productively transferred to computer protocols. Advances in this area could lead not only to improved health care at individual hospitals, but also to a dramatic change in the way patients are treated in the United States or even worldwide. Standardized data-collection and -interpretation systems would facilitate the development of a vast health-care network, connecting hospitals, laboratories, disease-control centers, and the like. Patients could be transferred from one hospital to another without painstaking translation of records. At present, a report prepared by one physician may not be satisfactory, or even intelligible, to another doctor.

Because of the decentralized, "cottage industry" nature of medicine, the development of universally accepted protocols will be difficult. But just as some vendors have been able to design spread-sheet or word-processing programs that are useful to a variety of users, so might some clever designer—with the help of forward-looking health-care experts—revolutionize health care with a well-designed system of medical standards for computerized systems. Such a development would mark a great advance in the capability of hospitals to care for the ill. ◆